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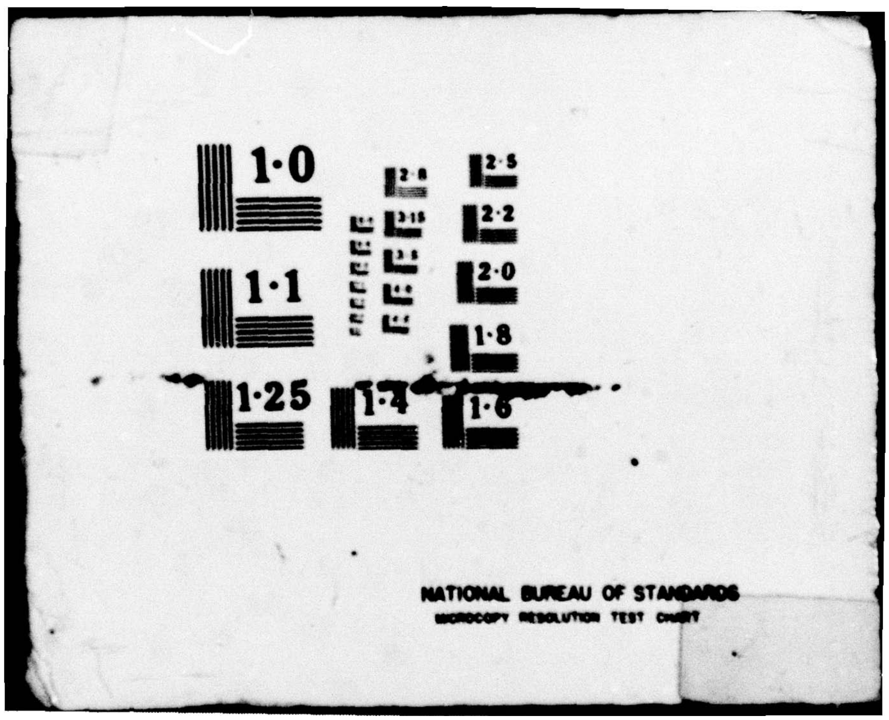
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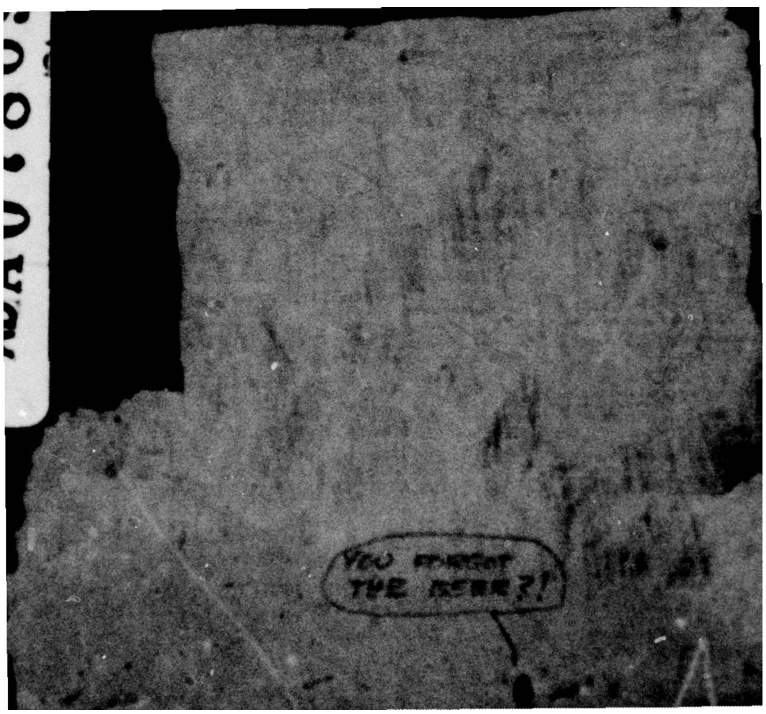
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Cover:

Iceberg in the sea ice of McMurdo Sound, Antarctica. The horizontal banding in the side wall is stratigraphy within the snow associated with annual accumulation events. The stratigraphy is in a sense analogous to tree ring growth patterns. The dark bands are high density snow or ice layers, the lighter bands are low density snow. The iceberg has suffered from wave erosion and calving from the undermined walls. As a result its sail has become elevated and a portion of what was the keel is exposed. The exposed keel is seen to bulge outward on an angle as a result of differential wave erosion and melting.

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Icebergs are discussed and categorized according to their size, shape, composition and color. A general overview of iceberg-producing areas in the Arctic and Antarctic is given, and their drift and deterioration are discussed.

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PREFACE

This short article on icebergs was written by Austin Kovacs, Research Civil Engineer, Applied Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory. It was prepared on request for inclusion in an encyclopedia volume devoted to the subject of snow and ice, the publication of which has been indefinitely postponed.

The author gratefully acknowledges the helpful comments of Gunars Abele, Stephen Ackley, Dr. Robert T. Martin and Francis Sayles.

ICEBERGS: AN OVERVIEW

Austin Kovacs

Icebergs are formed from freshwater glacial ice of land origin, through the "calving" of floating glaciers or ice shelves. They are generally categorized by shape:

Tabular (or table-topped)	Relatively horizontal or flat-topped berg with a length to height ratio of 10:1 or more. Average measured sail height to keel draft ratio* about 1:4.5 for bergs off the east coast of Canada, about 1:7.5 for bergs in the Beaufort Sea.
Blocky	Steep sides with horizontal top; very solid berg. Smaller than a tabular berg. Sail height to keel draft ratio about 1:4.
Dome	Rounded top. Sail height to keel draft ratio about 1:6.
Drydock	Eroded in such a way that the above-water portion consists of two or more columns or pinnacles. Sail height to keel draft ratio about 1:2.5.
Bergy bit	Glacial ice fragment about the size of a small house.
Growler	Small remnant of an iceberg. Generally less than 3 m high and 7 m wide.

The height to draft ratio of icebergs has been found to vary from about 1:1 (very unstable berg) to 1:11; the ratios given above are averages for each type of berg.

Icebergs are also categorized by their color: white, black and white, and bottle green. The white or bluish-white berg is by far the most common, making up about 99% of all icebergs. These bergs derive their color from the snow and ice of which they are made. Black and white icebergs derive their color from mud and stone debris, which may be diffused throughout much of the berg or concentrated in sharply defined layers or bands. Bottle green icebergs are seldom seen and virtually unstudied. As a result, the cause of their unique color remains unknown.

*A function of overall shape and density.

In the Arctic, most icebergs originate from glaciers on the west coast of Greenland. Other source areas are the east coast of Greenland and several eastern Canadian arctic islands -- Ellesmere, Devon and Baffin Islands in particular. Icebergs over 200 m thick sometimes originate from the glaciers in Severnaya Zemlya in the Soviet Arctic. Small bergy bit/growler size icebergs are carved from a few glaciers in southern Alaska. These icebergs generally melt near the site of their birth. Ice shelves on the north coast of Ellesmere Island occasionally produce tabular icebergs called ice islands. These bergs are solid ice and have been measured in excess of 30 x 30 km. Their thickness, however, is less that 50 m. During the 1970's more than 500 ice islands or ice island fragments (less than 50 m long) were observed off the southern Beaufort Sea coast of Alaska and Canada. Nearly 450 of these ice islands were observed in the winter of 1971-72.

Most of the icebergs in the Northern Hemisphere are found in the waters between Canada and Greenland. These bergs tend to be other than tabular. The highest iceberg measured was some 210 m high and the deepest keel was on the order of 650 m deep.

Mesoscale iceberg drift is difficult to predict. At times, their drift corresponds with local currents, but on other occasions they will sail with the wind or with neither current nor wind direction. In the latter case iceberg drift is influenced by the Coriolis force which imposes a transverse deflection, to the right in the Northern Hemisphere and to the left in the Southern Hemisphere, away from the direction of the driving force. In general, deep draft icebergs drift with the current, while small icebergs with shallow draft drift in response to the wind. Long-term drift, however, is with the currents southward toward the Grand Banks located off the southeastern coast of Newfoundland, Canada. Iceberg drift south of latitude 40°N is very infrequent. However, on very rare occasions an iceberg fragment will drift to the latitude of the Azores and Bermuda.

North Atlantic iceberg drift records show that the number of icebergs reaching the Grand Banks yearly varies significantly, from 0 to over 1000, e.g. nearly 1600 icebergs were sighted in 1973. It has been found that a strong correlation exists between the winter-spring mean air flow direction and speed off the Labrador-Newfoundland coasts and the number of icebergs observed to the south of Newfoundland. Strong westerly and northwesterly winds promote the southward movement of icebergs, whereas northerly and northeasterly winds drive icebergs into shallow coastal waters where many become grounded. Approximately 95% of the icebergs that reach the Grand Banks in a given year do so from March through June, and about 65% arrive during April and May.

The episode of the sinking of the luxury liner SS Titanic, after her collision with an iceberg, reminds us that icebergs pose a constant threat to shipping. This is particularly true along the eastern side of the Grand Banks where southbound icebergs tend to follow the 150 - 200 m depth contours at a velocity of 15 to 30 km per day. However, icebergs also pose a threat to transatlantic cables and proposed bottom-founded structures and pipelines associated with offshore hydrocarbon resource development. Icebergs can drift into shallow water where they may come aground, deeply gouge the seabed and thereby destroy a bottom-founded structure. This is highly possible off the east coast of Labrador and along the northern part of the Newfoundland Bank where hundreds of icebergs become stranded each season.

Fortunately, icebergs experience significant wasting during the long journey from the site of their birth to the open sea beyond the edge of the pack ice. For example by the time an iceberg reaches the Grand Banks it is about one-eighth its original size. Once in the open sea, they disintegrate rapidly through the action of storm seas and heavy swells, current effects, and scouring, as well as higher water temperatures. The overall result is that few large icebergs reach the Grand Banks, and those that do, rapidly waste away, on an average of 1 to 2 m a day, greatly reducing the threat to the shipping lanes farther south. The average annual iceberg drift limit for the north Atlantic is shown in Figure 1.

Great tabular icebergs occur only off Antarctica, where the ice flow from the continent pushes far out to sea to form large ice shelves. These floating ice shelves vary from 140 to 280 m in thickness at their edges. Unlike arctic bergs, which are all ice, the tabular icebergs calved from Antarctic ice shelves generally consist of snow and ice. The snow on the surface has a density of about 0.38 Mg/m^3. The density of the snow increases with depth, reaching 0.82 Mg/m^3 at about the 50-60 m depth. This is the density at which snow is no longer permeable and by definition becomes ice. At a depth of approximately 200 m the ice reaches a density of about 0.91 Mg/m^3 or close to that of pure ice which has a density of 0.916 Mg/m^3.

Large sections of floating ice shelves frequently break off and gradually drift northward through the Antarctic ice pack to the open seas beyond. The largest iceberg on record was observed in 1927; it was 160 km long and approximately 35 m high. Another berg seen in 1965 was 140 km long and had an area of approximately 7000 km^2 -- larger than the state of Rhode Island.

Tabular icebergs found drifting beyond the edge of the Antarctic pack ice are usually 12 to 40 m high and 100 to 400 m long and have a width to length ratio between 1:1.5 and 1:3. This indicates that soon after tabular icebergs leave the protection of the pack, the effects of sea swells, waves and uneven melting cause them to rapidly disintegrate into smaller fragments as shown in Figure 2.

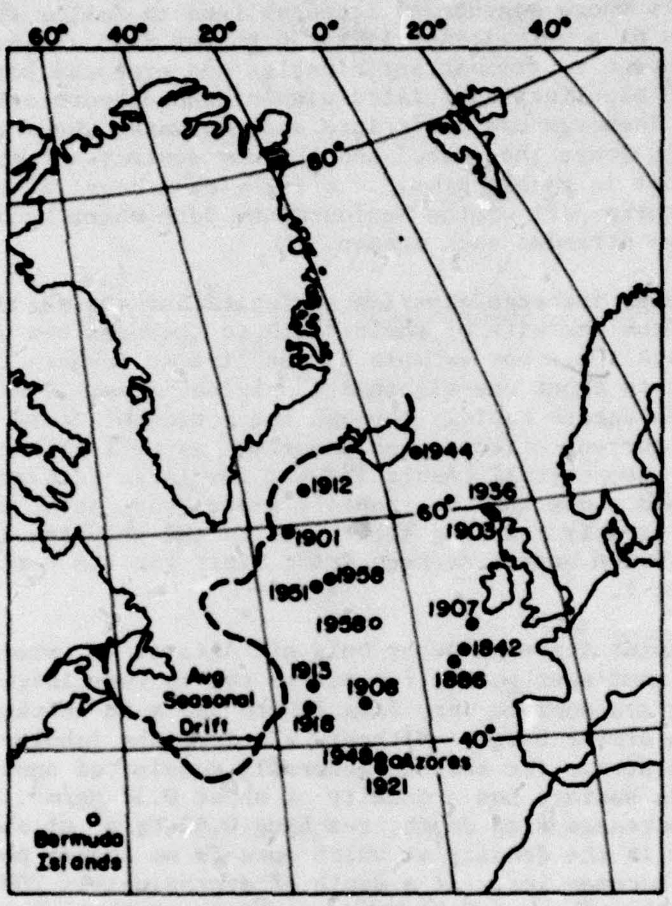

Figure 1. Average annual seasonal iceberg drift zone and the positions of some unusual iceberg observations in the North Atlantic Ocean.

Indeed, within the Antarctic circumpolar current, which has a temperature of less than 2°C, tens of thousands of icebergs exist, but north of the Antarctic Convergence, the surface waters have a slight northerly drift and the water temperature increases very rapidly. As a result, few icebergs survive to a latitude of 50°S and rarely do they reach 35°S in the Atlantic Ocean, 40°S in the Indian Ocean and

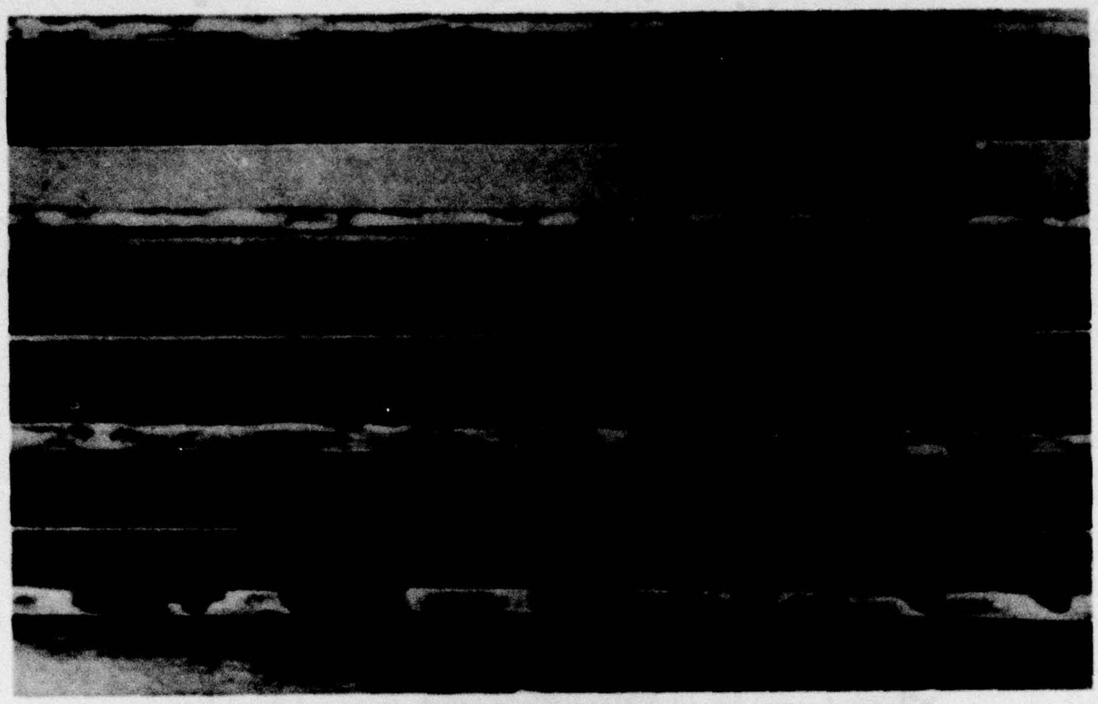

Figure 2. Sequence of photographs showing the disintegration of a tabular iceberg into many small fragments.

45°S in the Pacific Ocean. Even so, one iceberg fragment was seen in 1894 in the Atlantic Ocean as far north as 25°30'S, 25°40'W. The northern limit of iceberg drift observation around the Antarctic is shown in Figure 3.

CREDITS AND REFERENCES

Figure 1 is patterned after an illustration by R.P. Dinsmore in his 1971 paper, "A review of U.S. Coast Guard published data on icebergs in the North Atlantic," published in the Proceedings of the Canadian Seminar on Icebergs, Marine Commander Headquarters, Halifax, Nova Scotia.

Figure 2 is from Lebedev (1959).

The northern limit of iceberg sightings shown in Figure 3 was constructed from information given in V.S. Nazarov (1962) Ice of the Antarctic waters (in Russian). Rezul'taty Isledovanii Po Programme Meshdunavodnogo Geofizicheskogo Goda, Okeanologia, Vol. X, No. 6, Izd. Akad. Nauk SSSR, Moscow.

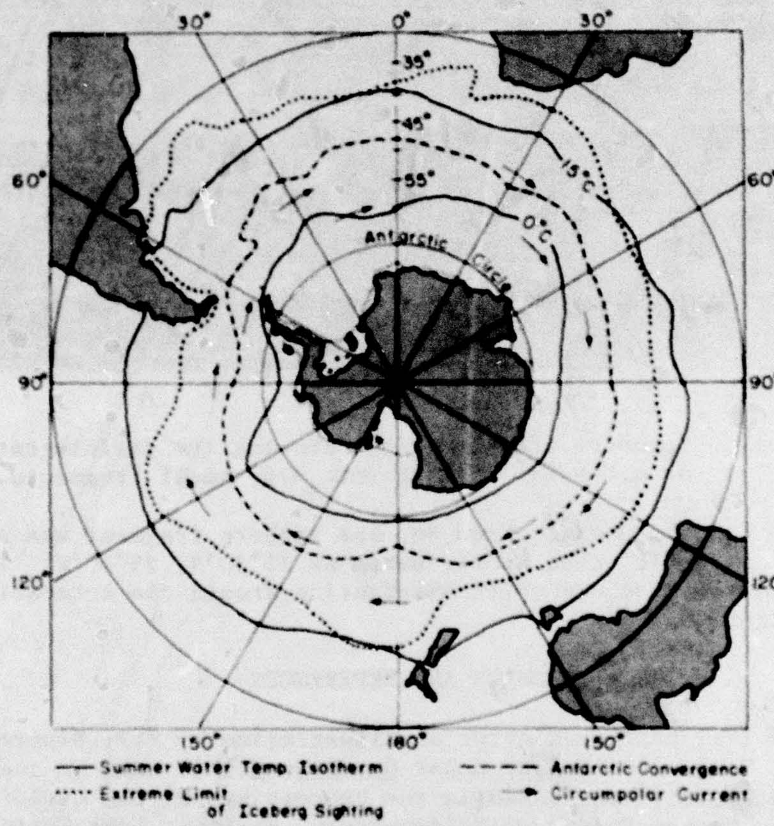

Figure 3. Northern limit of iceberg sightings around the Antarctic continent from 1773 to 1960. Note: The Antarctic convergence is the meeting place of the colder southern and warmer mid-latitude surface waters. Across this zone the water temperature may change two to three degrees in a very short distance.

Source material for this short overview on icebergs comprised numerous references. The sources most used were:

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